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Algal diversity in hot springs of Odisha

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ओडीशा के तप्त जलाशयों की शैवाल विविधता

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सारांश

ओडीशा राज्य के तरबेल, तप्तपानी, अट्री एवं देऊलझरी जैसे चार तप्त जलाशयों (60 से 35 डिग्री से. की सीमा में) और उनके जल प्लवनों से शैवाल की जातियाँ प्रगणित की गई हैं। साइनोफाइटा (साइनोप्रोकैरियोटा/साइनोबेक्टेरिया) क्लोरोफाइटा, कैरोफाइटा एवं हेटरोकोनटोफाइटा (बेसीलैरियोफाइसी) के अन्तर्गत 35 वंश से संबंधित कुल 50 शैवाल जातियां प्रतिवेदित की गई। *सियूडानबेना* (60 से 52 डिग्री से.), *फोरमिडियम* (45 से 38 डिग्री से.) *ओसिल्लेटोरिया* (42 से .4 डिग्री से.) एवं *नवीकुला* (35 डिग्री से.) पर ये उर्वर जातियां एक विशिष्ट तापमान पर पाई जाती हैं। साइनोफाइटा 35 जातियों को दर्शाती है एवं 60 से 36 डिग्री से. के उच्च तापमान प्रचुरता से पाये जाते है, जबकि 12 डायटम 45 से 35 डिग्री से. के कम तापमान पर पाये जाते हैं, इसमें क्रमशः *क्लोरेला, स्पाइरोगाइरा* एवं *कोसमारियम* वंश के क्लोराफाइटा का एक, कैरोफाइटा की दो जातियां शामिल हैं। अट्री, तप्तपानी के जातियां में समानता और तरबेल एवं देऊलझरी में समानता केवल 2 तक ही सीमित हैं। तप्तपानी एवं देऊलझरी की जातियों में केवल 1 में ही समानता है। परन्तु ओडीशा राज्य के इन चार तप्त जलाशयों में पादप संबंधी कोई समानता नहीं है ।

ABSTRACT

Algal flora of four hot springs e.g., Tarabela, Taptapani, Atri and Deulajhari and their overflows (temperature range 60–35 °C) of Odisha state was enumerated. A total of 50 species of algae belonging to 35 genera under Cyanophyta (Cyanoprokaryota/Cyanobacteria), Chlorophyta, Charophyta and Heterokontophyta (Bacillariophyceae) were reported. The species rich genera occurred at specific temperature gradients were *Pseudanabaena* (60–52 °C), *Phormidium* (45–38 °C), *Oscillatoria* (42–40 °C) and *Navicula* (35 °C). Cyanophyta represented by 35 species showing the dominance at higher range of temperature i.e., 60–36 °C, where as 12 diatoms occurred at lower temperature range 45–35 °C along with one Chlorophyta and two Charophyta of genera *Chlorella*, *Spirogyra* and *Cosmarium* respectively. Commonality of species between Atri and Taptapani as well as in Tarabela and Deulajhari is restricted to 2 only. Only one species is common between Taptapani and Deulajhari. But, there is no common organism in all the four hot springs of Odisha state.

Keywords: Algae, Hot Springs, India, Odisha, Temperature gradients

INTRODUCTION

Hot springs are thermal aquatic ecosystems distributed all over the world. There are several reports on the systematic account of algae and cyanobacteria of thermal springs (Prasad & Srivastava, 1965; Vasishta, 1968; Prasad & al., 1984; Hindák, 1978, 2001, 2008). Publications are also available on the water quality of thermal springs and their correlation with algae and cyanobacteria occurring there-in and their temperature limit (Jana, 1978; Jha &

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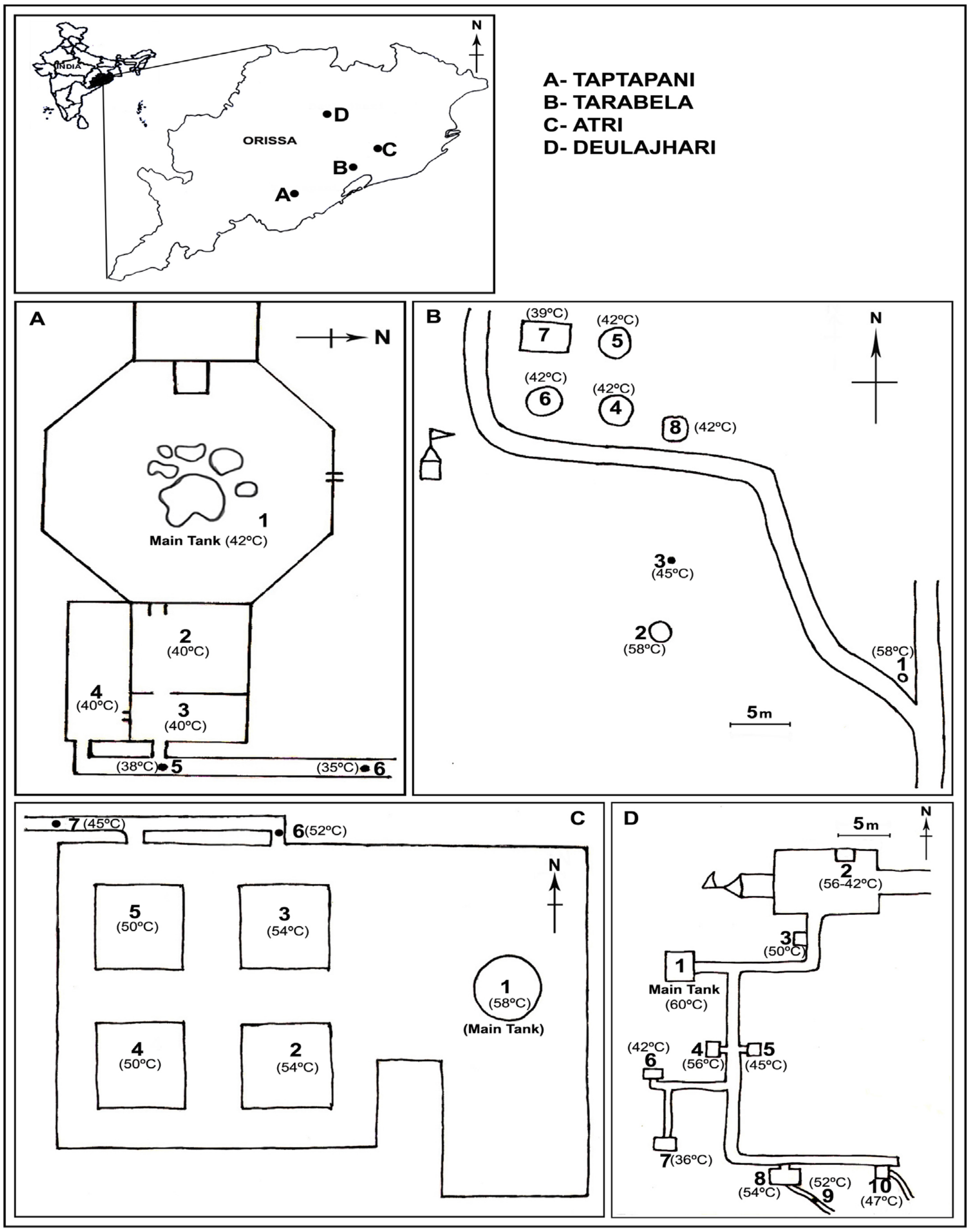

Fig -1: Diagrammatic representation of the four hot springs and their overflows of Odisha.

Kumar, 1986; Sinha & Chaubey, 1986; Jahangir & al., 2001; Sompong & al., 2005). In India of the 286 hot springs (Oldham & Oldham, 1882) four are located in Odisha state namely Taptapani, Atri, Tarabela and Deulajhari. Temperature of these hot springs ranges from 60–42 °C. The algal diversity of two of these springs, Atri and Taptapani have been documented earlier (Pattanaik & Rao, 1972; Rao & Pattanaik, 1975; Adhikary & Sahu, 1987), however, studies on correlation of occurrence of algae with the temperature gradient in these hot springs has not been studied yet. We report here the algal species occurring with respect to the temperature gradient of the unique habitat and their commonality in occurrence in all these four hot springs located in different regions of the state.

MATERIALS AND METHODS

Samples were collected from the main tank, bathing tank and the outlets of four hot springs namely Tarabela located at Bhapur, Nayagarh district (20° 15' 09.9"N and 85° 19'

10.8"E), Taptapani located at Taptapani, Ganjam district (19º 29' 4.9"N and 84º 23' 35.4"E), Atri located at Baghamari, Khurda district (20º 12' 24.4"N and 85º 30' 47.9"E), and Deulajhari located at Athamallik, Anugul district (20º 44' 24.6"N and 84º 29' 56.1"E) of the Odisha state (Fig. 1). Epilithic and biofilm samples were scraped with scalpel, collected using a forcep and stored in sterile specimen tubes from different collection sites of various thermal gradients. The samples were assigned with voucher numbers along with date of collection, preserved in formaldehyde (4 % v/v) and deposited at the Department of Biotechnology, Visva-Bharati. Microscopic study was made using Olympus BX41 Trinocular research microscope fitted with Nikon Coolpix 4500 digital camera. Standard monographs and research publications (Kützing, 1865, Turner, 1892, Pascher, 1913, Desikachary, 1959, Randhawa, 1959, Gandhi, 1960, Komárek & Fott, 1983, Prasad & Srivastava, 1992, Gärtner, 1995, Kant & Gupta, 1998, Komárek & Anagnostidis, 1998, 2005) were referred to identify different species of algae. Systematic enumeration of the algal species was done following (Krienitz, 2009).

RESULTS AND DISCUSSION

A total of 50 algal species were reported belonging to 35 genera under Cyanophyta (Cyanoprokaryota/Cyanobacteria), Chlorophyta, Charophyta and Heterokontophyta (Bacillariophyceae) from four hot springs of Odisha. They are enumerated systematically as follows along with their distribution in different hot springs of India as well as from other parts of the globe.

SYSTEMATIC ENUMERATION

CYANOPHYTA (CYANOPROKARYOTA/ CYANOBACTERIA)

1. **Aphanothece bullosa** (Kütz.) Rabenh., Fl. Eur. Alg. 2: 65. 1865. *Palmella bullosa* Kütz., Flora 19 (2): 14. 1836. **(Pl. 1, Fig. 1)**

Colonies mucilaginous, irregular with firm surface, grayish green, mucilage colorless with irregularly arranged cell, cells oval to elongate cylindrical with rounded ends, cell contents more or less homogenous, cells 6.6–11 μm long, 3.2–4 μm broad.

Habitat: Bluish green mat attached to the cemented walls of bathing tanks 50–54°C at Atri (Voucher number – 2023, 2030; date of collection – 09.11.2008).

Distribution – Waywood, Himachal Pradesh (Vasishta, 1968); Bashista, Punjab (Prasad & Srivastava, 1965); Bukhari and Manghopir, Pakisthan (Leghari & al., 2005); Piesťany and Sklené Teplice, Slovakia (Hindak, 1978); San Kamphaeng, Pong Dued and Jae Son, Thailand (Sompong & al., 2005); Tateyama, Toyama prefecture, Japan (Emoto & Yoneda, 1942).

2. **Aphanothece pallida** (Kütz.) Rabenh., Krypt. –Fl. Sachsen 1: 76. 1863. *Palmella pallida* Kütz., Phyc. Germ. 149. 1845. **(Pl. 1, Fig. 2)**

Colonies microscopic, mucilaginous, pink, young stage, densely arranged cells, mucilage colorless, irregular, cells oval to cylindrical, 3 μm long and 2 μm broad, rounded cell apices.

Habitat: Pinkish white floating slimy mass in Deulajhari at 42°C (Voucher number – 2116; date of collection – 30.11.2008).

3. **Synechococcus lividus** J.J. Copel., Ann. N.Y. Acad. Sci. 36: 56. 1936. **(Pl. 1, Fig. 3)**

Cells solitary, elongated, straight to slight bent or curved, granule present in either end or both end or at middle of each cell, cells cylindrical, 1.3 μm broad and 4.6–9.3 μm long.

Habitat: Bluish green mat attached to cemented wall of bathing tank in Atri at 54°C (Voucher number – 2018; date of collection – 09.11.2008).

Distribution- Taptapani, Ganjam, Odisha (Adhikary & Sahu, 1987); Bhimbandh, Bihar (Sinha & Chaubey, 1986); Yellowstone National Park, USA (Doemel & Brock, 1977; Miller & al., 1998); San Kamphaeng, Pong Deud, Teppanom, Male Fang, Doi Saket, Jae Son, Tha Pai, Mae Jun and Huai Mak lium, Thailand (Sompong & al., 2005).

4. **Synechococcus elongatus** (Nägeli) Nägeli, Gatt. Einzell. Alg.: 56. 1849. *Protococcus elongatus* Nägeli in Kütz., Sp. alg.: 197. 1849. **(Pl. 1, Fig. 4)**

Cell bluish green, solitary, cylindrical, irregularly curved, finely granulated cell content with rounded apices, cells 6–7 times longer than broad, 5 μm broad, 34 μm long.

Habitat: Bluish green mat attached to bathing tank in Atri at 50°C (Voucher number – 2030; date of collection – 09.11.2008).

Distribution – Taptapani, Ganjam, Odisha (Adhikary & Sahu, 1987); Vyas Kund and Ganga Jamuna, Rajgir, Bihar (Jha & Kumar, 1986); Bukhari and Manghopir, Pakistan (Leghari & al., 2005); Tateyama, Toyama prefecture, Japan (Emoto & Yoneda, 1942).

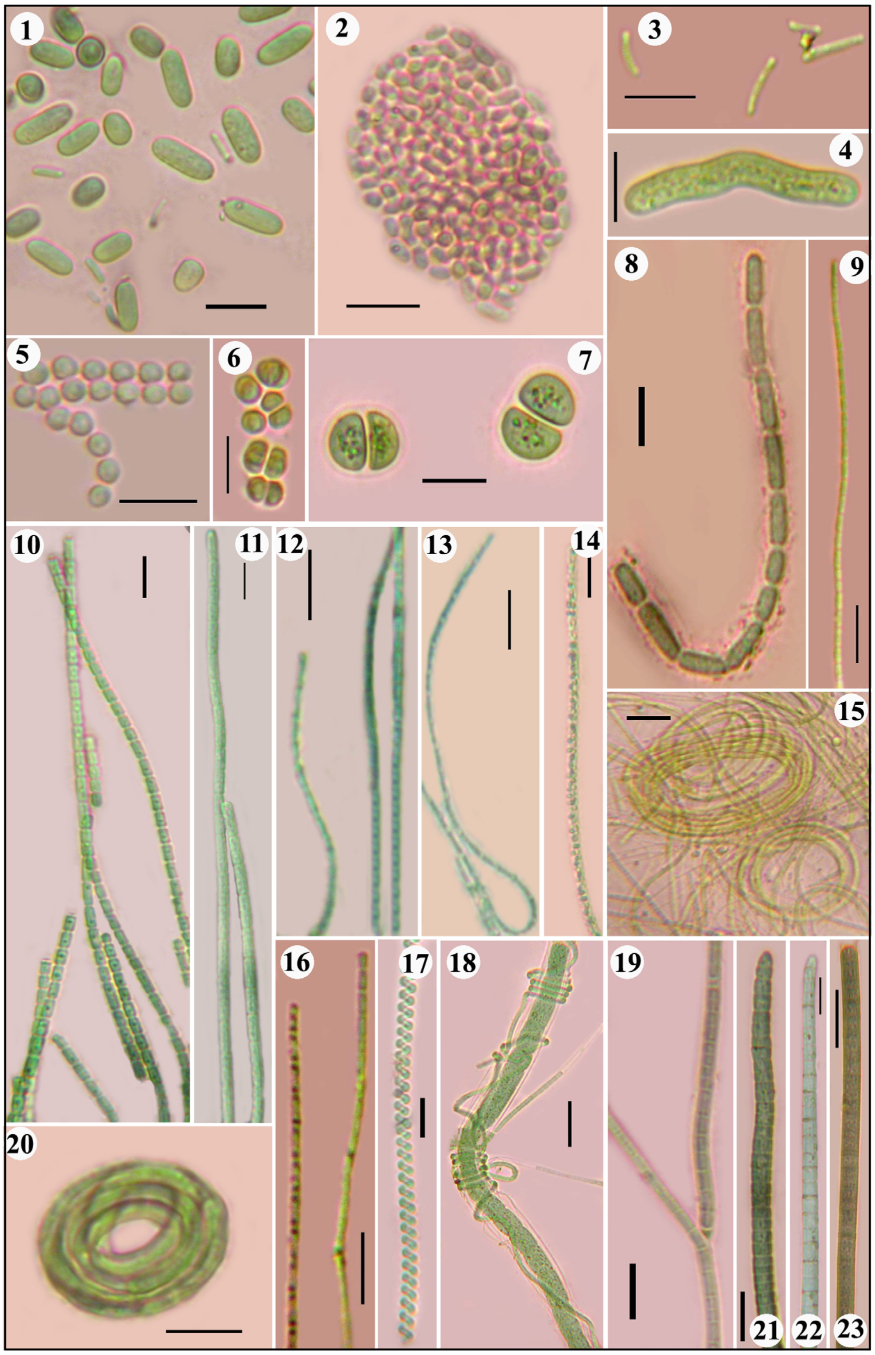

Plate-1 (Fig. 1-23): 1. *Aphnothece bullosa* 2. *Aphanothece pallida* 3. *Synechococcus lividus* 4. *Synechococcus elongatus* 5. *Synechocystis minuscola* 6. *Gloeocapsopsis crepidinum* 7. *Chroococcus turgidus* 8. *Pseudoanabaena contorta* 9. *Pseudoanabaena cartenata* 10. *Pseudoanabaena thermalis* 11. *Pseudoanabaena limnetica* 12. *Pseudoanabaena batrachospermorum* 13. *Limnothrix planctonica* 14. *Limnothrix guttulata* 15. *Planktolyngbya circumcreta* 16. *Jaaginema quadripunctulatum* 17. *Spirulina major* 18. *Leibleinia calotrichicola* 19. *Leptolyngbya terebrans* 20. *Arthrospira santannae* 21. *Phormidium boryanum* 22. *Kamptonema formosum* 23. *Phormidium irriguum*

Scale : Figs.1-17 & 19-22 = 10µm; Figs. 18 & 23 = 20µm

5. Synechocystis minuscula Woron., Arch. Hydrobiol. 17: 642. 1926. **(Pl. 1, Fig. 5)**

Cells solitary or two in together, arranged in a chain, globular with grayish green, cell contents homogenous, envelop very thin, hyaline, cells 2.5–3 µm in diameter.

Habitat: Bluish green mat attached to cemented wall of bathing tank in Atri at 54°C (Voucher number – 2027; date of collection – 09.11.2008).

Distribution – San Kamphaeng, Pong Dued, Teppanom and Jae son, Thailand (Sompong & al., 2005).

6. Gloeocapsopsis crepidinum (Thur.) Komárek, Bull. Natl. Sci. Mus. Tokyo, ser. B (Bot.) 19: 24. 1993. *Protococcus crepidinum* Thur., Mém. Soc. Imp. Sci. Nat. Cherbourg 2: 388. 1854. **(Pl. 1, Fig. 6)**

Colonies large, gelatinous, irregular, cell hemispherical to spherical, 3.5–5.5 µm in diameter, envelope thin, colorless and diffluent, not lamellate, hyaline, cell content homogenous.

Habitat: Green mat attached to outlet in Atri at 54°C (Voucher number – 1665; date of collection – 15.08.2008) and biofilm on outlet drain in Taptapani at 38°C (Voucher number – 2027; date of collection – 09.11.2008).

7. Chroococcus turgidus (Kütz.) Nägeli, Gatt. Einzell. Alg.: 46. 1849. *Protococcus turgidus* Kütz., Tab. Phyc. 1: 5. 1846. **(Pl. 1, Fig. 7)**

Colonies microscopic, 2 celled, rarely solitary, mucilaginous envelope distinct, firmly copying the cell out line; cell hemispherical, blue green, 7–8 µm diameter; colony 17 µm long and 14–15 µm broad.

Habitat: Floating mat in Taptapani at 42°C (Voucher number – 1660; date of collection – 15.08.2008).

Distribution – Himachal Pradesh (Visishta, 1968); Tuwa, Gujarat (Thomas & Gonzalves, 1965a).

8. Pseudanabaena contorta Kling & J. Watson, Hydrobiologia, 502: 385. 2003. **(Pl. 1, Fig. 8)**

Thallus bluish green forming mat, trichome solitary, usually irregularly spiral or coiled, deeply constricted at cross walls; sheath hyaline, mucilaginous; cell 2.2 µm broad, 8–10 µm long, cell content homogenous.

Habitat: Bluish green mat in Tarabela at 58°C (Voucher number – 1686; date of collection – 17.08.2008).

9. Pseudanabaena catenata Lauterborn, Verh. Naturh. – Med. Ver. Heidelberg, ser. 2, 13: 437. 1915. **(Pl. 1, Fig. 9)**

Trichome long, solitary, constricted at the cross wall, not attenuated, cells cylindrical, 1 µm broad, 2–3 times longer than broad, cell content homogenous, without aerotopes, rounded cell apices.

Habitat: Bluish green mat attached to outlet of bathing tank in Atri at 54°C (Voucher number – 2018; date of collection – 09.11.2008).

Distribution – Borgoria, Kenya (Hindak, 2001); San Kamphaeng, Pong Dued, Teppanom, Mae Fang, Jae Son and Tha Pai, Thailand (Sompong & al., 2005).

10. Pseudanabaena thermalis Anagn., Preslia 73: 360. 2001. **(Pl. 1, Fig. 10)**

Trichome bluish green, straight, solitary, constricted, not attenuated at the ends; cells cylindrical with rounded ends, inter connected with hyaline bridges, cells 4 µm long with two small polar aerotopes.

Habitat: Attached to dead leaf surface and floating mat in Deulajhari at 45°C (Voucher number – 2113; date of collection – 30.11.2008).

11. Pseudanabaena limnetica (Lemmerm.) Komárek, Sborn. Jihočesk. Muz. Českých Budéjovicích, Přír. Védy 14: 162. 1974. *Oscillatoria limnetica* Lemmerm., Ber. Deutsch. Bot. Ges. 18: 310. 1900. **(Pl. 1, Fig. 11)**

Trichome bluish green, solitary, straight, cross walls hyaline, translucent, slightly constricted, without aerotopes, not attenuated at the ends; cells long, cylindrical, 2.5 µm broad, 8–10 µm long, cell contents homogenous, apical cells rounded.

Habitat: Bluish green mat attached to the tank wall in Deulajhari at 60°C (Voucher number – 2121; date of collection – 30.11.2008.

Distribution– Bukhari and Manghopir, Pakistan (Leghari & al. 2005).

12. Pseudanabaena batrachospermorum (Skuja) Anagn. & Komárek, Arch. Hydrobiol. Suppl. 80: 383. 1988. *Oscillatoria batrachospermorum* Skuja, Nova Acta R. Soc. Sci. Upsal., ser. 4, 18 (3): 52. 1964. **(Pl. 1, Fig. 12)**

Trichome pale green, variously lengthened, irregularly curved translucent cross wall, slightly constricted, cells cylindrical, 4.5 µm long, 0.9–1 µm broad .

Habitat: Bluish green mat attached to dead leaf surface in Deulajhari at 52°C (Voucher number – 2119; date of collection – 30.11.2008.

13. Limnothrix planktonica (Wolosz.) M.E. Meffert, Arch. Hydrobiol. Suppl. (Algol. Stud. 50–53) 80: 277. 1988. *Oscillatoria planctonica* Wolosz., Rozpr. Wydz. Mat. – Przyr. Akad. Umiej., ser. 3, 11: 303. 1911. **(Pl. 1, Fig. 13)**

Trichome solitary, straight or slightly curved, pale green, without sheath, trichome very thin, 1.1 µm broad, cells longer than broad, 3–4.5 µm long, gas vacuoles absent, apical cell bluntly rounded.

Habitat: Pinkish-white slimy floating mass in Deulajhari at 42°C (Voucher number – 2116; date of collection – 30.11.2008).

14. Limnothrix guttulata (Goor) Umezaki & M. Watan., Jap. J. Phycol. 42: 207. 1994. *Oscillatoria guttulata* Goor, Rec. Trav. Bot. Néerl. 15: 255. 1918. **(Pl. 1, Fig. 14)**

Trichomes solitary, straight, pale blue green with scattered aerotopes, not constricted, cross walls slightly visible, apical cell not attenuated, without calyptra, trichome 2.5 µm broad.

Habitat: Bluish green mat floating as well as attached to soil in Deulajhari at 40°C (Voucher number – 2107; date of collection – 30.11.2008).

15. Jaaginema quadripunctulatum (Brühl & Biswas) Anagn. & Komárek, Arch. Hydrobiol. Suppl. (Algol. Stud. 50–53) 80: 396. 1988. *Oscillatoria quadripunctulata* Brühl & Biswas, J. Dep. Sc. Univ. Calcutta 4 (1): 5. 1922. **(Pl. 1, Fig. 16)**

Thallus pale blue green, trichome nearly straight, not constricted, cross wall indistinct, cells 2.5–3 µm long, 1–1.2 µm broad, granule on either side of cross wall present, not attenuated, apical cell rounded.

Habitat: Bluish green mat attached to outlet drain in Atri at 54°C (Voucher number – 2018; date of collection – 09.11.2008).

16. Spirulina major Kütz. ex Gomont, Ann. Sc. Nat. Bot., ser. 7, 16: 250. 1893. **(Pl. 1, Fig. 17)**

Trichomes pale to bright blue green, 1.2 µm wide, regularly screw like coiled, coils left handed, and distance between spirals is 4–4.5 µm.

Habitat: Bluish green mat attached to rock surface of main tank in Taptapani at 42°C (Voucher number – 1667; date of collection – 17.08.2008).

Distribution – Waywood, Himachal Pradesh (Vasishta 1968).

17. Planktolyngbya circumcreta (G.S. West) Anagn. & Komárek, Arch. Hydrobiol. Suppl. (Algol. Stud. 50–53) 80: 394. 1988. *Lyngbya circumcreta* G.S. West, J. Linn. Soc., London Bot. 38: 174. 1907. **(Pl. 1, Fig. 15)**

Filaments solitary, spirally coiled, 2 µm wide, coils 33 µm broad, making 2–3 turns, sheath firm, colorless, trichomes pale blue green, cross walls not constricted, apical cell rounded.

Habitat: Blue green floating mat in main tank in Atri at 58°C (Voucher number – 2017; date of collection – 09.11.2008).

18. Leibleinia calotrichicola (J.J. Copel.) Anagn. & Komárek, Arch. Hydrobiol. Suppl. (Algol. Stud. 50–53) 80: 394. 1988. *Lyngbya calotrichicola* J.J. Copel., Ann. N.Y. Acad. Sci. 36: 191. 1936. **(Pl. 1, Fig. 18)**

Filaments on and among other filamentous cyanoprokaryotes, partly in close screw like cells around the filaments, in part loosely and irregularly twisted around them; sheath thin, colorless, slightly visible; trichome blue green, 1.8–2 µm broad, cross wall indistinct.

Habitat: Floating mat in main tank in Taptapani at 42°C (Voucher number – 1660; date of collection – 15.08.2008).

19. Leptolyngbya terebrans (Bornet & Flahault) Anagn. & Komárek, Arch. Hydrobiol. Suppl. (Algol. Stud. 50–53) 80: 393. 1988. *Plectonema terebrans* Bornet & Flahault, Bull. Soc. Bot., France 36: 103. 1889. **(Pl. 1, Fig. 19)**

Filament bluish green, flexuous, pseudo branched, sheath very thin, not lamellate, colorless; trichome not constricted, cells longer than broad, 2 µm broad, 3.5 µm long.

Habitat: Floating mat in main tank in Taptapani at 42°C (Voucher number – 1660; date of collection – 15.08.2008).

20. Arthrospira santannae Komárek & Komárk.-Legn., Hoehnea 34 (1): 51. 2007. **(Pl. 1, Fig. 20)**

Trichome solitary, pale blue green, irregularly ±densely coiled, not constricted at cross walls, not attenuated at the ends, calyptra absent, trichome 2.8 µm broad, isodimetric, without aerotopes.

Habitat: Bluish green mat attached to cemented wall of tank in Deulajhari at 36°C (Voucher number – 2117; date of collection – 30.11.2008).

21. Phormidium boryanum (C. Agardh ex Gomont) Anagn. & Komárek, Arch. Hydrobiol. Suppl. (Algol. Stud. 50–53) 80: 405. 1988. *Oscillatoria boryana* C. Agardh ex Gomont, Ann. Sci. Nat. Bot., ser. 7, 16: 234. 1892. **(Pl. 1, Fig. 21**)

Trichome straight or slightly screwed, constricted at the cross walls; cells 3.8–5.3 µm broad and 3 µm long; end cell rounded or less pointed, not capitate; calyptra absent.

Habitat: Bluish green mat attached to wall of the main tank in Taptapani at 42°C (Voucher number – 1661; date of collection – 15.08.2008).

Distribution- San Kamphaeng, Pong Dued, Teppanom, Male Fang, Doi Saket, Jae Son, Tha Pai, Mae Jun and Huai Mak Lium, Thailand (Sompong & al. 2005).

22. Kamptonema formosum (Bory ex Gomont) O. Strunecký & al., Preslia, 86: 204. 2014. *Oscillatoria formosa* Bory ex Gomont, Ann. Sci. Nat. Bot., ser. 7, 16: 230. 1892. **(Pl. 1, Fig. 22)**

Thallus blue green; trichome straight or slightly bent at tip, calyptra absent, not capitate, not constricted at cross walls, 4–5.5 µm broad, slightly tapering towards apices, cells some what broader than long or quadrate, 3–4.5 µm long.

Habitat: Bluish green floating mat on outlet drain in Tarabela at 45°C (Voucher number – 1689; date of collection – 17.08.2008.

23. Phormidium irrigum (Kütz. ex Gomont) Anagn. & Komárek, Arch. Hydrobiol. Suppl. (Algol. Stud. 50–53) 80: 405. 1988. *Oscillatoria irrigua* Kütz. ex Gomont, Ann. Sci. Nat. Bot., ser. 7, 16: 218. 1892. **(Pl. 1, Fig. 23)**

Trichomes long, blue green, sheath absent or rarely developed; not constricted at the cross walls, not attenuated at the ends; apical cells convex; cell 7.6µm broad and 3.8–4.7 µm long.

Habitat: Biofilm on rock surface of outlet drain in Taptapani at 38°C (Voucher number – 1665; date of collection – 15.08.2008).

24. Oscillatoria princeps Vaucher ex Gomont, Ann. Sc. Nat. Bot., ser. 7, 16: 201. 1892. **(Pl. 2, Fig. 1)**

Trichomes blue green, mostly straight, not constricted at the cross walls, 8.5 µm broad, slightly attenuated at the apices and bent, cells 3–4 µm long, end cells flat rounded, slightly capitate.

Habitat: Blue green mat floating as well as attached to soil in Deulajhari at 40°C (Voucher number – 2107; date of collection – 30.11.2008).

Distribution – Atri, Khurda, Odisha (Adhikary and Sahu 1987); Vyas Kund and Ganga jamuna, Rajgir, Bihar (Jha & Kumar, 1986).

25. Phormidium breve (Kütz. ex Gomont) Anagn. & Komárek, Arch. Hydrobiol. Suppl. (Algol. Stud. 50–53) 80: 405. 1988. *Oscillatoria brevis* Kütz. ex Gomont, Ann. Sc. Nat. Bot., ser. 7, 16: 229. 1892. **(Pl. 2, Fig. 2)**

Thallus blue green, trichome in a group, straight, suddenly bent towards ends and capitate, cell wall thick and alight wrinkled margin; cells 2.2–6 µm long and 12–14.5 µm broad; floating mat.

Habitat: Floating filamentous mat in Tarabela at 39°C (Voucher number – 1695; date of collection – 17.08.2008).

26. Oscillatoria jenensis Schmidle, Jahrb. Wiss. Bot. 60: 572. 1921. **(Pl. 2, Fig. 3)**

Thallus dark bluish green, trichome without sheath, cells 18 µm broad, 4.5–5.5 µm long, cell wall thick, filament not constricted, cross walls indistinctly granulated, trichome shortly attenuated at the ends, hook like bent, 11 µm wide near the ends, apical cell convex, rounded, not capitates.

Habitat: Blue green mat attached to soil in Deulajhari at 40°C (Voucher number – 2107; date of collection – 30.11.2008).

27. Lyngbya majuscula Harvey ex Gomont, Ann. Sc. Nat. Bot., ser. 7, 16: 131. 1892. **(Pl. 2, Fig. 4)**

Filament dark bluish green, sheathed, sheath colorless, lamellate; trichome cylindrical, not constricted, ungranulated cross walls, not attenuated; cells discoid, 34–40 µm broad, 4–5 µm long, broader than long, hormogonia aggregated forming swelled gibbous structure at the apices of filament, apical cell rounded.

Habitat: Floating filamentous mat in Tarabela at 39°C (Voucher number – 1696, 1697; date of collection – 17.08.2008).

Distribution – Ganeshpuri and Palli, Bombay, Maharastra; Bhakreshwar, West Bengal (Vasishta, 1968).

28. Scytonema burmanicum Skuja, Nova Acta R. Soc. Sc. Upsal., ser. 4, 14 (5): 34. 1949. **(Pl. 2, Fig. 8)**

Thallus brownish green, filamentous, densely aggregated, false branched, thin lamellated sheath, filament 18.2 µm broad, less constricted, false branches solitary, generally elongate; trichome13.2 µm broad; cells broader than length, 8.3–11 µm long.

Habitat: Hard lamellated mat on outlet drain in Tarabela at 45°C (Voucher number – 1687; date of collection – 17.08.2008.

29. Tolypothrix distorta Kütz. ex Bornet & Flahault var. **samoensis** Wille, Hedwigia 53: 145. 1913. **(Pl. 2, Fig. 9)**

Thallus filamentous, interwoven, frequently branched, sheathed, constricted at the cross walls; cells barrel shaped quadratic or long; heterocyst intercalary, 12.1 µm broad and 23.3 µm long; filament is 13.3 µm broad; cells 6.6–8.8 µm long and 7.7 µm broad.

Habitat: Floating mat in main tank in Taptapani at 42°C (Voucher number – 1660; date of collection – 15.08.2008.

30. Calothrix marchica Lemmerm. var. **crassa** C.B. Rao, Proc. Indian Acad. Sc., sect. B, 6: 349. 1937. **(Pl. 2, Fig. 10)**

Filaments bluish green, trichome straight or slightly bent, solitary, broader at base, gradually attenuated towards apex, constricted cross walls; cells nearly as long as broad, end cell conical, some what pointed; heterocyst single, basal, nearly spherical 8 µm broad; cells 9–10 µm broad, 6–9 µm long.

Habitat: Bluish green mat on rock surface of main tank in Taptapani at 42°C (Voucher number – 1661; date of collection – 15.08.2008).

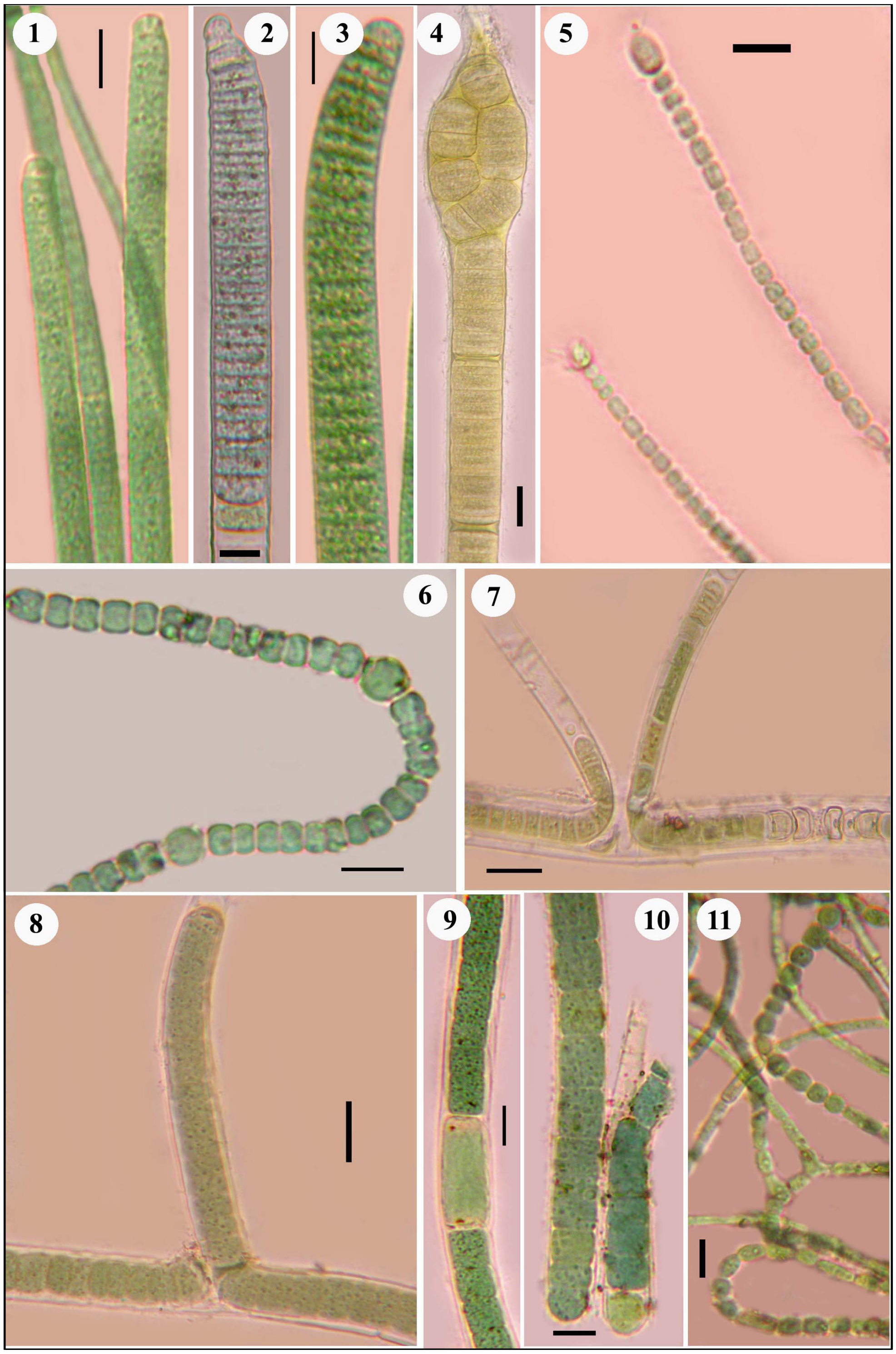

Plate-2 (Fig. 1-11): 1.*Oscillatoria priceps* 2. *Phormidium breve* 3. *Oscillatoria jenensis* 4. *Lyngbya majuscula* 5. *Cylindrospermum sphaerica* 6. *Nostoc spongiaeforme* var. *varians* 7. *Aulosira pseudoramosa* 8. *Scytonema burmanicum* 9. *Tolypothrix distorta* var. *samoensis* 10. *Calothrix marchica* var. *crassa* 11. *Westiellopsis prolifica*

Scale: Figs. 1-3, 5, 6, & 9-11 = 10µm; Figs. 7 & 8 = 20µm; Fig. 4 = 30µm

31. Cylindrospermum sphaericum B.N. Prasad, J. Indian. Bot. Soc. 31: 358. 1952. **(Pl. 2, Fig. 5)**

Trichome light blue green, constricted at cross walls; cells cylindrical, 3–4.8 µm long, 3 µm broad ; heterocyst sub conical to ellipsoidal, one at each end of the trichome, formed singly, 5.5–7 µm long, 4.5 µm broad .

Habitat: Hard lamellated mat on outlet drain in Tarabela at 45°C (Voucher number – 1687; date of collection – 17.08.2008).

32. Aulosira pseudoramosa Bharadwaja, Ann. Bot. 47 (185): 137. 1933. **(Pl. 2, Fig. 7)**

Filament straight; sheath thick, 4.5–5.7 µm stratified, false branched; cells broader than long or barrel shaped, 6.6 µm long, 5.7–9.5 µm broad, 2–3 cells lying dormant near the heterocyst; heterocyst one or more, intercalary.

Habitat: Hard lamellated mat on outlet drain in Tarabela at 45°C (Voucher number – 1687; date of collection – 17.08.2008).

33. Nostoc spongiaeforme C. Agardh ex Bornet & Flahault var. **varians** C.B. Rao, Proc. Indian Acad. Sci., sect. B, 6: 359. 1937. **(Pl. 2, Fig. 6)**

Thallus blue green, cell barrel shaped 5–5.6 µm broad and 4.2–7 µm long; heterocyst rounded, intercalary, broader than the trichome 5.5–7 µmin diameter; end cells conical with rounded ends.

Habitat: Bluish green mat attached to rock surface of main tank in Taptapani at 42°C (Voucher number – 1667; date of collection – 15.08.2008).

34. Mastigoclaudus laminosus Cohn ex Kirchn. in Engler & Prantl, Nat. Pflanzenfam. 1 (1): 81. 1898. **(Pl. 3, Fig. 1)**

Thallus dark bluish green, spongy, branched, sheath absent or hyaline, filament with uniseriate moniliform cells, cells are barrel shaped to rounded, short branches arising on one side, true lateral branching as well as false branching often present; heterocyst intercalary; cells 5–7 µm long and 4–6 µm broad.

Habitat: Floating mat in main tank in Taptapani at 42°C (Voucher number – 1660; date of collection – 15.08.2008).

Distribution – Taptapani, Ganjam, Odisha (Adhikary and Sahu 1987); Teppanom and Male Fang, Thailand (Sompong & al., 2005); Tateyama, Toyama prefecture, Japan (Emoto & Yoneda, 1942); Mountrainer National park and Yellowstone National park, U.S.A (Stockner, 1969).

35. Westiellopsis prolifica Janet, Ann. Bot. N. S. 5 (17): 170. 1941. **(Pl. 2, Fig. 11)**

Thallus filamentous with true branching, filaments without a sheath and consisting of a single row of cells, main filament with barrel shaped cells or longer than broad, 2.2–3.5 µm broad, 11–13 µm long; heterocyst intercalary, cylindrical, 10–16 µm long and 3.5 µm broad; terminal portion of secondary branches forming chain of rounded cells (pseudohormocysts) of 5.5 µm in diameter.

Habitat: Blue green mat attached to wall of main tank in Atri at 58°C (Voucher number – 2016; date of collection – 09.11.2008).

CHLOROPHYTA

36. Chlorella vulgaris Beij., Bot. Zeit. 48: 758. 1890. **(Pl. 3, Fig. 3)**

Cell solitary, unicellular, green, spherical, cell wall thin, chloroplast cup shaped with a distinct pyrenoid at centre; cell is 5 µm in diameter.

Habitat: Planktonic in the tank in Deulajhari at 36°C (Voucher number – 2117; date of collection – 30.11.2008).

Distribution: Mangho Pir, Pakistan (Jahangir & al., 2001).

37. Spirogyra schmidtii West & G.S. West in Schmidt, Bot. Tidsskr. 24: 161. 1901. **(Pl. 3, Fig. 2)**

Thallus filamentous, straight, vegetative cell much longer than broad, 266.56 µm long and 35 µm broad, plane end walls, 3 chloroplasts making 2.5 turns.

Habitat: Floating filamentous mat in tank in Tarabela at 39°C (Voucher number – 1696; date of collection – 17.08.2008.

38. Cosmarium melanosporum W. Archer & R. Roy, Ann. Mag. Nat. Hist., ser. 5, 12: 124. 1883. **(Pl. 3, Fig. 4)**

Cell small, longer than broad, deeply constricted sinus, wide open; semi cells semicircular with broad rounded apices; cell 21 µm long, 17 µm broad, isthmus 5.5 µm broad.

Habitat: Planktonic in the outlet drain of Tarabela at 45°C (Voucher number – 1687; date of collection – 17.08.2008).

HETEROKONTOPHYTA / BACILLARIOPHYCEAE

39. Achnanthes lanceolata (Bréb. ex Kütz.) Grun. var. **rostrata** (Østrup) Hust. in Pascher, Süssw. – Fl. 10 (2): 208. 1930. *Achnanthes rostrata* Østrup, Bot. Tidsskr. 25:35. 1903. **(Pl. 3, Fig. 5)**

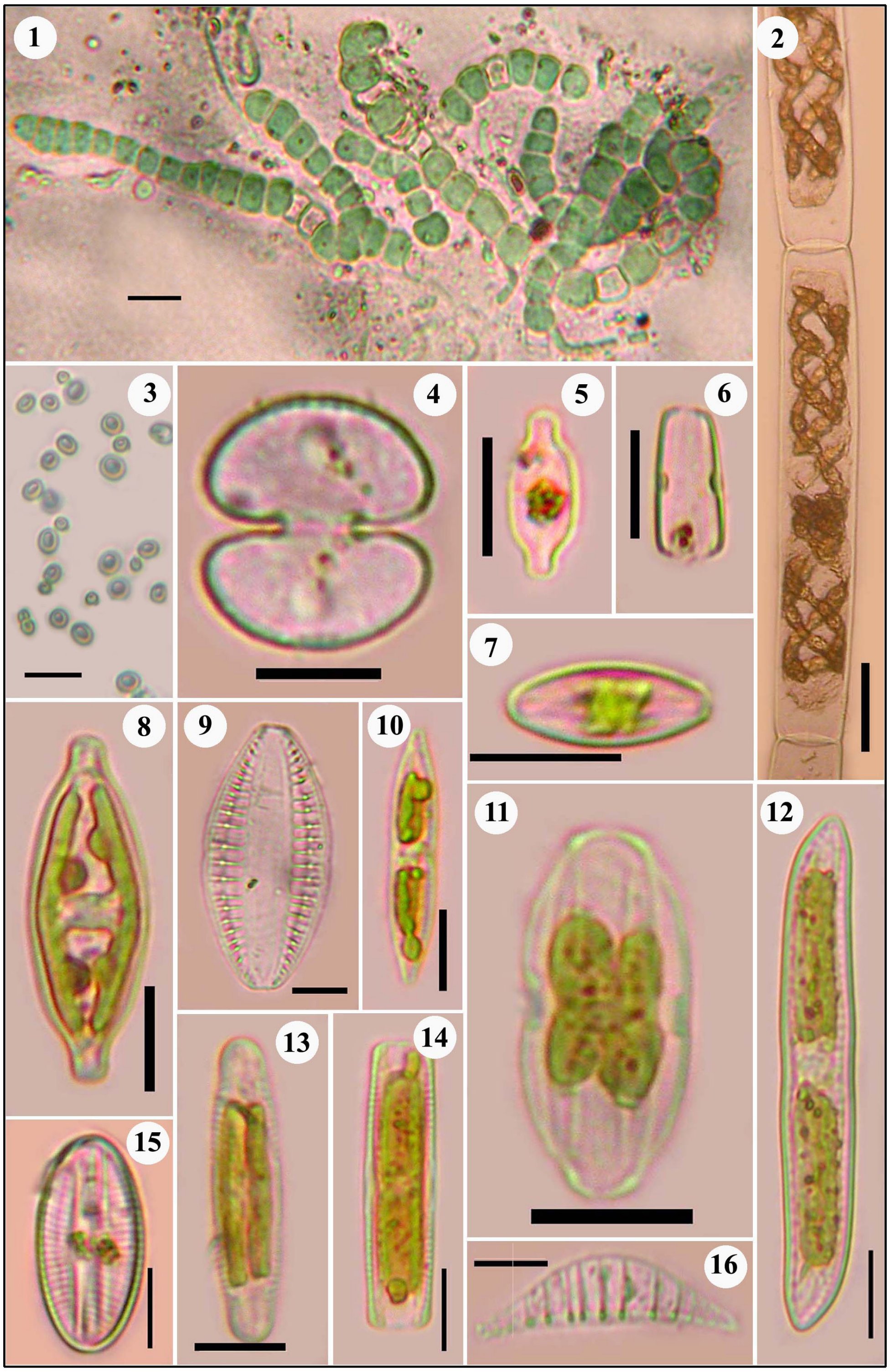

Plate-3 (Fig. 1-16): 1. *Mastigocladus laminosus* 2. *Spirogyra schmidtii* 3. *Chlorella vulgaris* 4. *Cosmarium melanosporum* 5. *Achnanthes lanceolata* var. *rostrata* 6. *Surirella minuta* 7. *Navicula fluens*, 8. *Navicula microspora*, 9. *Rhopalodia operculata*, 10. *Nitzschia vasnii* 11. *Halamophora veneta* 12. *Nitzschia obtusa* var. *scalpelliformis* 13. *Navicula protracta* 14. *Navicula exilis* 15. *Cocconeis striata* 16. *Rhopalodia gibberula* Scale : Figs. 1-16 = 10 µm

Valves small, somewhat quadrate with abruptly narrowed produced rostrate ends; valve gradually widening towards center; central areas broad, somewhat rectangular; striation not clearly visible, valve is 12 µm long and 5–6 µm broad.

Habitat: Biofilm on rock surface of outlet drain in Taptapani at 35°C (Voucher number – 1666; date of collection – 15.08.2008).

Distribution: Cowboy, California (Ekins & Rushforth, 1986); Mountrainer National park and Yellowstone National park, U.S.A (Stockner, 1969)

40. Cocconeis striata Ehrenb., Ber. K. Acad. Wiss. Berlin 1842: 338. 1842. **(Pl. 3, Fig. 15)**

Valve elliptical or broadly lanceolate, symmetrical, transverse striation, valve 12 µm broad and 25 µm long.

Habitat: Attached to wall of the tank in Deulajhari at 36°C (Voucher number – 2118; date of collection – 30.11.2008.

41. Navicula fluens Hust. in Ant. Schmidt, Atlas: pl. 370: 37. 1930. **(Pl. 3, Fig. 7)**

Valves small, elliptical lanceolate with rounded ends, raphe thin, straight, median, axial area very narrow, linear, central area somewhat elliptical, striae fine, lineate, slightly radiate through out the valve, 13.4 µm long and 5.6 µm broad.

Habitat: Attached to rock surface of outlet drain in Taptapani at 35°C (Voucher number – 1666; date of collection – 15.08.2008).

42. Navicula microspora Kant & P. Gupta, Algal Fl. Ladakh 157. 1998. **(Pl. 3, Fig. 8)**

Frustules elliptical – lanceolate, rostrate apices, capitate, pseudoraphe at the centre, axial area broad, striation not visible in fresh material, longer than broad, 44.2 µm long and 11.3 µm broad.

Habitat: Biofilm attached to rock surface of outlet drain in Taptapani at 35°C (Voucher number – 1666; date of collection – 15.08.2008).

43. Navicula protracta (Grunow) Cleve, K. Svenska Vet. – Acad. Handl., ser 4, 26 (2): 140. 1894. *Navicula cruciccula* (W. Sm.) Donkin var. *protracta* Grunow in Cleve & Grunow, K. Svenska Vet. –Acad. Handl., ser 4, 17 (2): 35. 1880. **(Pl. 3, Fig. 13)**

Frustules small, linear to slightly linear lanceolate with broadly rounded rostrate ends, striation not clear in fresh material, longer than broad, 39.2 µm long and 9.7 µm broad.

Habitat: Biofilm attached to rock surface of outlet drain in Taptapani at 35°C (Voucher number – 1666; date of collection – 15.08.2008).

44. Navicula exilis Kütz., Bacillarien: 95. 1844. **(Pl. 3, Fig. 14)**

Valve symmetrical, ends are of same size, frustule rectangular, solitary, ends flat, striae marginal, valve thick, 35.2 µm long and 8 µm broad.

Habitat: Biofilm attached to rock surface of outlet drain in Taptapani at 35°C (Voucher number – 1666; date of collection – 15.08.2008).

45. Halamphora veneta (Kütz.) Levkov, Diat. Eur. 5: 242. 2009. *Amphora veneta* Kütz., Bacillarien: 108. 1844. **(Pl. 3, Fig. 11)**

Frustules elliptical with rounded ends, margins medianly constricted; raphe thin, linear, striae lineate, 26 µm long, 11 µm broad.

Habitat: Biofilm attached to rock surface of outlet drain in Taptapani at 35°C (Voucher number – 1666; date of collection – 15.08.2008).

Distribution: Cowboy, California, U.S.A. (Ekins & Rushforth, 1986).

46. Nitzschia obtusa W. Sm. var. **scalpelliformis** Grunow in Van Heurck, Syn. Diat. Belg. 67. 1881. **(Pl. 3, Fig. 12)**

Valve linear, very slightly sigmoid with obliquely wedge-shaped acutely rounded ends; slightly notched in the middle, valve is 59–62 µm long and 9 µm broad.

Habitat: Biofilm attached to rock surface of outlet drain in Taptapani at 35°C (Voucher number – 1666; date of collection – 15.08.2008.

47. Nitzschia vasnii H.P. Gandhi, J. Indian Bot. Soc. 39 (4): 566. 1960. **(Pl. 3, Fig. 10)**

Valve narrow lanceolate or linear lanceolate, very small, valve margins almost parallel with cuneate ends, valve 35 µm long and 6 µm broad.

Habitat: Biofilm attached to rock surface of outlet drain in Taptapani at 35°C (Voucher number – 1666; date of collection – 15.08.2008).

48. Rhopalodia gibberula (Ehrenb.) O. Müll. in G. Karst., Wiss. Meeresuntersuch. Kiel. 4: 97. 1899. *Eunotia gibberula* Ehrenb., Abh. K. Akad. Wiss. Berlin, Physik. Kl. 1841: 414. 1843. **(Pl. 3, Fig. 16)**

Frustules solitary, valve view lunate to sickle shaped or elliptic, clavate, medianly inflated, ends truncated, dorsal margin convex, costae distinct, coarse, radial; striae fine, punctuate, valve 35 µm long and 7.2 µm broad .

Table 1: Cyanobacteria and microalgae recorded from four hot springs and their overflows in Odisha.

Sl. No.	Organisms Cyanophyta (Cyanoprokayota/Cyanobacteria)	Tarabela (58–36ºC)	Taptapani (42–35ºC)	Atri (58–38ºC)	Deulajhari (60–36ºC)
1	*Aphanothece bullosa*	–	–	+	–
2	*Aphanothece pallida*	–	–	–	+
3	*Synechococcus lividus*	–	–	+	–
4	*Synechococcus elongatus*	–	–	+	–
5	*Synechocystis minuscola*	–	–	+	–
6	*Gloeocapsopsis crepidinum*	–	+	+	–
7	*Chroococcus turgidus*	–	+	–	–
8	*Pseudanabaena contorta*	+	–	–	–
9	*Pseudanabaena cartenata*	+	–	–	–
10	*Pseudanabaena thermalis*	–	–	–	+
11	*Pseudanabaena limnetica*	–	–	–	+
12	*Pseudanabaena batrachospermorum*	–	–	–	+
13	*Limnothrix planctonica*	–	–	–	+
14	*Limnothrix guttulata*	–	–	–	+
15	*Jaaginema quadripunctulatum*	–	–	+	–
16	*Spirulina major*	+	+	–	–
17	*Planktolyngbya circumcreta*	–	–	+	–
18	*Leibleinia calotrichicola*	–	+	–	–
19	*Leptolyngbya terebrans*	–	+	–	+
20	*Arthrospira santannae*	–	–	–	+
21	*Phormidium boryanum*	–	+	–	–
22	*Phormidium irriguum*	–	+	–	–
23	*Phormidium breve*	+	–	–	–
24	*Kamptonema formosum*	+	–	–	–
25	*Oscillatoria princeps*	–	–	–	+
26	*Oscillatoria jenensis*	–	–	–	+
27	*Lyngbya majuscula*	+	–	–	–
28	*Cylindrospermum sphaerica*	+	–	–	–
29	*Nostoc spongiaeforme* var. *varians*	–	+	–	–
30	*Aulosira pseudoramosa*	+	–	–	–
31	*Scytonema burmanicum*	+	–	–	–
32	*Tolypothrix distorta* var. *samoensis*	–	+	–	–
33	*Calothrix marchica* var. *crassa*	–	+	–	–
34	*Westiellopsis prolifica*	–	–	+	–
35	*Mastigocladus laminosus*	–	+	+	–
	Chlorophyta				
36	*Chlorella vulgaris*	+	–	–	–
	Charophyta				
37	*Spirogyra schmidtii*	+	–	–	–
38	*Cosmarium melanosporum*	–	–	–	+
	Heterokontophyta (Bacillariophyceae)				
39	*Achnanthes lanceolata* var. *rostrata*	–	+	–	–
40	*Cocconeis striata*	+	–	–	+
41	*Navicula fluens*	–	+	–	–
42	*Navicula microspora*	–	+	–	–
43	*Navicula protracta*	–	+	–	–
44	*Navicula exilis*	–	+	–	–
45	*Halamophora veneta*	–	+	–	–
46	*Nitzschia vasnii*	–	+	–	–
47	*Nitzschia obtusa* var. *scalpelliformis*	–	+	–	–
48	*Rhopalodia gibberula*	+	–	–	+
49	*Rhopalodia operculata*	+	–	–	–
50	*Surirella minuta*	–	+	–	–

Table 2: Comparison of the algal genera occurring at different temperatures in the hot springs of India (32–81.5 °C) Pakistan (40–47 °C), Thailand (30–80 °C), Kenya (80 °C), Slovakia (52 °C), U.S.A. (37–74 °C) and Japan (20–79 °C).

	India	Pakistan	Thailand	Kenya	Slovakia	U.S.A.	Japan
Cyanophyta (Cyanobacteria)							
Cyanothece	–	–	–	–	+	–	–
Cyanobacterium	–	–	+	–	–	–	–
Aphanothece	+	+	+	–	+	–	+
Synechococcus	+	+	+	+	–	+	+
Bacularia	–	–	+	–	–	–	–
Cyanocomperia	–	–	–	+	–	–	–
Synechocystis	+	+	+	+	–	+	–
Aphanocapsa	–	+	–	–	–	+	–
Microcystis	+	–	–	–	–	–	–
Merismopedia	–	+	–	–	–	–	–
Gloeocapsa	+	–	+	–	–	–	+
Choococcus	+	+	+	+	+	–	+
Gloeocapsopsis	+	–	–	–	–	–	–
Cyannosarcina	–	–	+	–	–	–	–
Chlorogloea	+	–	–	–	–	–	+
Siphononema	–	–	–	–	+	–	–
Onkonema	–	–	+	–	–	–	–
Chroococidiopsis	+	–	+	–	+	–	–
Myxosarcina	–	–	–	–	+	–	–
Xenococcus	–	–	–	–	–	–	+
Pleurocapsa	–	+	–	–	–	+	+
Pseudanabaena	+	–	+	+	–	–	–
Limnothrix	+	–	–	–	–	–	–
Jaaginema	+	–	–	–	–	–	–
Spirulina	+	+	–	+	–	+	–
Planktolyngbya	+	–	–	–	–	–	–
Leibleinia	+	–	–	–	–	–	–
Leptolyngbya	+	–	–	–	–	–	–
Isocystis	–	–	–	+	–	–	–
Arthrospira	+	–	–	–	–	–	–
Phormidium	+	+	+	+	–	+	+
Oscillatoria	+	+	+	+	–	+	+
Lyngbya	+	+	+	–	–	–	+
Symploca	–	–	+	–	–	+	–
Microcoleus	+	–	–	–	–	–	+
Cylindrospermum	+	+	–	–	–	–	+
Anabaena	+	–	–	–	–	–	–
Nostoc	+	–	–	–	–	–	+
Nodularia	+	–	–	–	–	–	–
Aulosira	+	–	–	–	–	–	–

(Continued)

	India	Pakistan	Thailand	Kenya	Slovakia	U.S.A.	Japan
Scytonema	+	–	+	–	–	–	–
Tolypothrix	+	–	–	–	–	–	–
Microchaete	+	–	–	–	–	–	+
Calothrix	+	–	+	–	–	–	–
Haplosiphon	+	–	–	–	–	–	–
Chlorogloeopsis	–	–	–	–	+	–	–
Mastigocladus	+	–	+	–	–	+	+
Westiellopsis	+	–	–	–	–	–	–
Chlorophyta							
Chlorococcum	–	+	–	–	–	–	–
Chlorella	+	+	–	–	–	–	–
Kirchneriella	–	+	–	–	–	–	–
Scenedesmus	–	+	–	–	–	–	–
Microspora	–	–	–	–	–	–	+
Charophyta *Spirogyra*	+	–	–	–	–	–	–
Closterium	–	–	–	–	–	–	+
Cosmarium	+	–	–	–	–		+
Bacillariophyceae							
Cyclotella	–	–	–	–	–	+	–
Stephanodiscus	–	–	–	–	–	+	–
Tabellaria	–	–	–	–	–	+	–
Denticula	–	–	–	–	–	+	–
Diatoma	–	–	–	–	–	+	–
Eunotia	–	–	–	–	–	+	–
Achnanthes	+	–	–	–	–	+	+
Cocconeis	+	–	–	–	–	+	–
Mastogloia	–	–	–	–	–	+	–
Diploneis	–	–	–	–	–	+	–
Anomoioneis	+	–	–	–	–	+	–
Fragilaria	+	–	–	–	–	–	–
Synedra	–	–	–	–	–	+	–
Amphora	+	–	–	–	–	+	–
Epithemia	–	–	–	–	–	+	–
Navicula	+	+	–	–	–	+	+
Caloneis	–	–	–	–	–	+	–
Pinnularia	–	–	–	–	–	+	–
Gomphonema	–	–	–	–	–	+	+
Stauroneis	+	–	–	–	–	+	–
Cymbella	+	+	–	–	–	–	–
Encyonema	–	–	–	–	–	+	–
Nitzschia	+	–	–	–	–	+	–
Rhopalodia	+	–	–	–	–	+	–
Surirella	+	–	–	–	–	+	–

Table 3: Algal taxa recorded at different temperature gradients in hot springs and their overflows in Odisha.

Temperature °C	Organisms
60 – 56 °C	*Pseudanabaena limnetica*
58°C	*Pseudanabaena contorta, Mastigocladus laminosus, Westiellopsis prolifica*
58 – 54°C	*Planktolyngbya circumcreta*
56 – 45°C	*Pseudoanabaena thermalis*
54 – 50°C	*Synechocystis minuscula*
54 – 38°C	*Gloeocapsopsis crepidinum*
54 – 50°C	*Aphanothece bullosa*
54°C	*Synechococcus lividus, Jaaginema quadripunctulatum*
54 – 52°C	*Pseudanabaena catenata*
52°C	*Pseudanabaena catenata, Pseudanabaena batrachospermorum*
50°C	*Synechococcus elongates*
45 – 42°C	*Rhopalodia operculata*
45 – 36°C	*Rhopalodia gibberula*
45°C	*Kamptonema formosum, Cylindrospermum sphaerica, Aulosira pseudoramosa, Scytonema burmanicum*
45 – 36°C	*Cocconeis striata*
42 – 40°C	*Leptolyngbya terebrans*
42 – 40°C	*Phormidium boryanum*
42°C	*Aphanothece pallida, Chroococcus turgidus, Limnothrix planctonica, Spirulina major, Leibleinia calotrichicola, Phormidium breve, Nostoc spongiaeforme* var. *varians, Tolypothrix distorta* var. *samoensis, Calothrix marchica* var. *crassa, Cosmarium melanosporum*
40 – 38°C	*Phormidium irriguum*
40°C	*Limnothrix guttulata, Oscillatoria princeps, Oscillatoria janensis*
39°C	*Lyngbya majuscula, Spirogyra schmidtii*
38°C	*Gloeocapsopsis crepidinum*
36°C	*Arthrospira santannae, Chlorella vulgaris,*
35°C	*Achnanthes lanceolate var. rostrata, Navicula fluens, Navicula microspora, Navicula protracta, Navicula exilis, Halamophora veneta, Nitzschia vasnii, Nitzschia obtusa, Surirella minuta*

Habitat: Attached to outlet drain in Tarabela at 45°C (Voucher number – 1687; date of collection – 17.08.2008).

Distribution: Cowboy, California (Ekins & Rushforth, 1986); Mountrainer National park and Yellowstone National park, U.S.A (Stockner, 1969).

49. Rhopalodia operculata (C. Agardh) Håk., Beih. Nova Hedwigia 64: 166. 1979. *Frustulia operculata* C. Agardh, Flora 10 (40): 627. 1827. **(Pl. 3, Fig. 9)**

Valve solitary, linear in girdle view, elliptic or lanceolate, broad median portion with constriction, apices wide rounded; striae transverse, wide apart from each other; valve 57 μm long and 22.5 μm broad.

Habitat: Attached to wall of tank in Deulajhari at 36°C (Voucher number – 2118; date of collection – 30.11.2008) and attached to outlet drain in Tarabela at 45°C (Voucher number – 1687; date of collection – 17.08.2008).

Distribution: Cowboy, California, U.S.A. (Ekins & Rushforth, 1986).

50. Surirella minuta Bréb., Consid. Diat.: 17. 1838. **(Pl. 3, Fig. 6)**

Valve solitary, linear, rectangular in girdle view, 14 μm long and 6.25–8 μm broad, indistinct costae and striae.

Habitat: Biofilm attached to rock surface of outlet drain in Taptapani at 35°C (Voucher number – 1666; date of collection – 15.08.2008).

Cyanobacteria and microalgae occurring in the 4 thermal springs and their overflows at a temperature gradient between 60–35°C has been documented.

A maximum number of 35 species of cyanobacteria (Cyanophyta) occurred in these hot springs (Table 1) of which 2 species were atleast common to two hot springs. These are *Gloeocapsopsis crepidinum* and *Mastigocladus laminsus* in Atri and Taptapani at a temperature 58–54˚C; *Leptolyngbya terebrans* in Taptapani and Deulajhari at 42–40˚C and two diatoms *Cocconeis striata* and *Rhopalodia operculata* in Tarabela and Deulajhari at 45–36˚C. Of these only *Mastigocladus laminosus* was reported widely distributed species found in the hot springs of India, Thailand, U.S.A. and Japan at 80–36˚C temperature but not in the thermal springs of Pakistan, Kenya and Slovakia (Table 2). Even the species *Synechococcus bigranulatus* and *Phormidium laminosus* which occurred in the other hot springs of the globe did not occur in the springs of India at 83–32˚C. The cyanobacteria species belong to genera *Pseudanabaena, Mastigocladus, Westiellopsis, Planktolyngbya, Synechocystis, Gloeocapsopsis, Aphanothece, Synechococcus, Jaaginema, Phormidium, Cylindrospermum, Aulosira, Scytonema, Leptolyngbya, Croococcus, Limnothrix, Spirulina, Leibleinia, Oscillatoria, Nostoc, Tolypothrix, calothrix, Lyngbya* and *Arthrospira* exclusively occurred in the hot springs at 60–36˚C temperature (Table-3). When the water temperature is lowered in the overflows of these springs many micro algal taxa under Chlorophyta, Charophyta and Heterokontophyta (Bacillariophyceae) occurred. However, few diatom species of genera *Achnanthes, Navicula, Anomoineis, Amphora, Nitzschia* and *Surirella* also occurred at 35˚C temperature in the bathing tanks which receive hot water from the source of the springs. These results showed that the hot springs of India has a typical distributional pattern of microalgae and cyanobacteria which is different from those of temperate regions.

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